1.6 Biodiversity and the Heritage of Our Lands

Figure D1.44: People have many different connections with the environment.

Individuals and groups of people who live in towns, cities, and farms all interact with the environment. Virtually every human activity will have a spinoff effect on the environment, but it's sometimes a challenge to understand all the connections. This is illustrated in the following two stories that may, at first, seem to have very little in common. If you enjoy the challenge of trying to guess endings to suspenseful movies, you may enjoy trying to discover the connections between these two descriptions.

One story describes woodland caribou and the other describes a shopping trip to a large urban shopping mall. As you read each description, try to identify as many connections as possible between details of the two stories. Following the caribou tracks across this page will hopefully get you off to a good start.

Woodland Caribou

Figure D1.45: Both mature male and female caribou have antlers, but male antlers are larger and have more points.

The woodland caribou is a member of the deer family. The caribou have large, crescent-shaped hooves that are ideally suited for travelling in the terrain of Alberta's boreal forests—deep snow in winter and the soft, spongy peat of muskeg in summer. The winter diet of the woodland caribou consists largely of tree **lichens** that are found in mature boreal forests.

It takes at least 80 years for a forest to grow enough tree lichens to support the caribou. In the summer, the caribou diet includes willows and wildflowers, as well as ground lichens.

These animals are considered to be an **endangered species** in Alberta because their survival is in question.

- lichen: an organism formed by the symbiotic association of a fungus and a photosynthetic alga
- endangered species: a species that may soon no longer exist within certain regions and/or may be threatened with imminent extinction

Figure D1.46: Many people call this kind of tree lichen old man's beard.

Shopping Trip

Imagine you just arrived at the home of a friend, Ravi, who lives in Calgary. While sifting through the weekly pile of flyers, you notice that many stores in the city's largest mall have huge sales. So, you and Ravi decide to drive to the mall in search of bargains.

Figure D1.47: It takes time to drive to the mall.

Since Ravi lives in a suburb on the city's outskirts, it takes about 35 minutes to drive to the mall and find a parking spot. Once inside, the hunt for the best deals begins with comparison shopping and lots of walking between stores. After all this shopping, it's time for lunch at a fast-food restaurant. When finished, you empty your tray that's full of paper food wrappers, empty cardboard containers, and a soft-drink cup. Now it's time to carry all the shopping bags loaded with your purchases to the car for the 35-minute ride back to Ravi's house.

Figure D1.48: The materials used in packaging can be recycled.

Luckily, Ravi lives in a city with a recycling program; so, once you've unpacked all your purchases you can put all the paper, plastic, and cardboard packaging in the proper recycling bins. As you sort through this, Ravi laughs and says, "It's crazy—this is just like eating fast food at the mall. All this packaging seems to take up more room than the stuff it was wrapped in."

Looking for the Interconnections

Now that you have read the two stories, how do they interconnect? What does the endangered species status of the woodland caribou have to do with a 35-minute ride to a mall? How does a large pile of packaging materials connect to tree lichen? In this lesson you will have a chance to see these connections as you explore the powerful impact that people have on the natural environment.

Practice

46. In the definition of lichen, it was stated that a lichen is formed by the symbiotic association of a fungus and a photosynthetic alga.
    a. Explain the meaning of symbiotic association.
    b. The fungus in the lichen contains microscopic fibres that provide the alga with a place to grow. The fungus also supplies the alga with water and minerals that these fibres filter from dust particles and moisture in the air. Identify the contribution that the alga makes to this association.
47. In the mall story, references were made to the use of paper products and to the consumption of fossil fuels.
    a. List the uses of paper products noted in the story. Also, list those that were not mentioned but that would likely still have played a role in the shopping trip.
    b. List the uses of petroleum and natural gas mentioned in the story. Add other uses that were not described but that would likely still have played a role in the shopping trip.

Habitat Fragmentation

People are considered to be healthy if they are free of disease and if they can readily heal themselves of minor infections, small cuts, and bruises. In other words, assuming you have access to adequate resources—like food, water, and shelter—you are considered healthy if your body is both self-sustaining and self-regulating.

In a similar way, an ecosystem is considered to be healthy if it is free of stress sources and if it can recover on its own from disturbances that disrupt its normal functioning. Sources of stress for an ecosystem include things like pollution, a loss of vegetation, a disruption of the water flow, and the introduction of a new species. These events are comparable to diseases in the human body because they interfere with an ecosystem's ability to sustain itself and to regulate all of its essential processes.

habitat fragmentation: the conversion of formerly continuous habitat into patches separated by non-habitat areas

Alberta's boreal forests are experiencing stress due to human activities. Timber harvesting, roads, mining, pipelines, power lines, and petroleum and natural gas exploration all require the removal of trees and lead to **habitat fragmentation**.

Habitat fragmentation in Alberta's boreal forests usually involves cutting corridors through the forest so that people have access to natural resources. The idea of habitat fragmentation is best understood through an examination of aerial photographs.

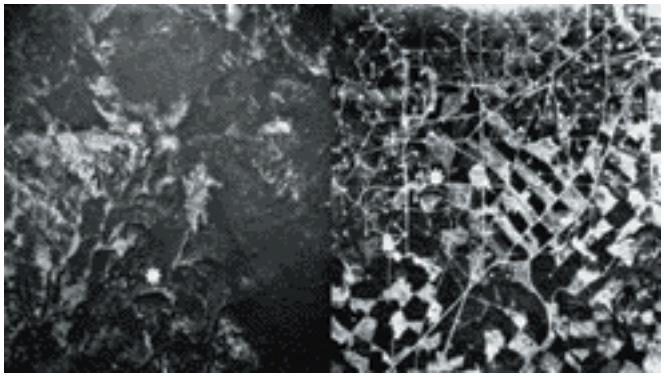
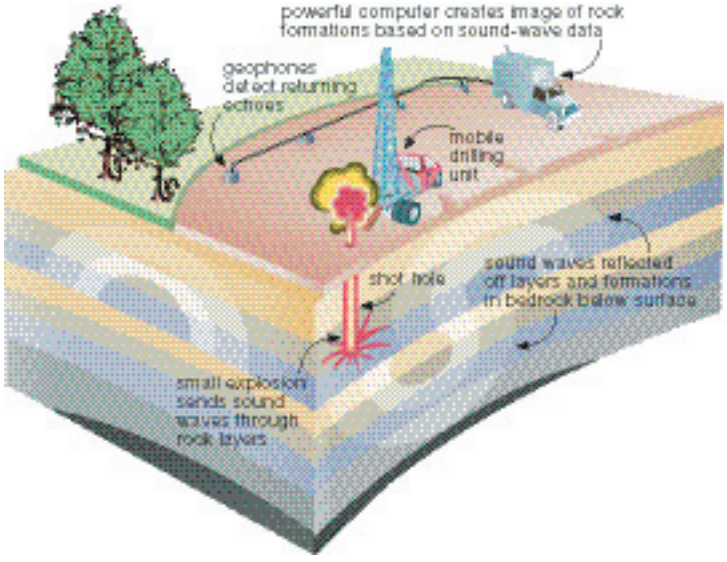


Figure D1.49: Alberta's Swan Hills forest ecosystem is shown in 1949 (left) and 1991 (right).

One source of habitat fragmentation in the boreal forest is seismic exploration conducted by companies searching for new sources of petroleum and natural gas. To gather information about subsurface rock formations, seismic waves are sent through the ground to probe the structure of underground rock formations.

The Seismic Exploration Process


powerful computer creates image of rock formations based on sound-wave data
geophones detect returning echoes
mobile drilling unit
shot hole
sound waves reflected off layers and formations in bedrock below surface
small explosion sends sound waves through rock layers

The sound waves are usually generated by explosive charges detonated at the bottom of shot holes drilled from 6 m to 20 m into the ground. The echoes of these waves are detected by a long line of sensitive microphones, called geophones. These geophones then send the collected data for a computer analysis.

Figure D1.50: From the air, a collection of access roads and seismic lines looks like a spider's web.

Habitat fragmentation can occur as a result of seismic exploration. The company builds access roads to the area to be explored, sets up an area to act as a camp for the seismic crew, and removes shrubs and trees to create seismic lines for equipment and vehicles. This process is compounded by the fact that competing companies may conduct independent seismic explorations over the same area. The result is that the forest landscape can become crisscrossed with a collection of access roads and seismic lines that from the air look like a spider's web. The impact of these seismic lines and access roads is significant to the woodland caribou. Cleared areas generate more habitat for moose. As the moose population increases, predators like wolves are attracted to the area, where they make effective use of the seismic lines to gain quick access and spot potential prey. The caribou are most vulnerable to the wolves, so they suffer the greatest losses. The chain of events responsible for the decline of the caribou begins with habitat fragmentation.

Practice

48. Explain the sequence of events that starts with habitat fragmentation and ends with a declining population of the woodland caribou.
49. List some of the advantages of hand-cut, low-impact seismic lines.

Habitat Destruction

Figure D1.51: Logging is a major industry in Alberta.

Almost 75% of the boreal forest in Alberta has been leased to companies for drilling, mining, and logging. Logging not only supplies lumber and solid wood products for the construction industry, but it also supplies the raw materials to make paper.

DID YOU KNOW?

- On average, each Canadian consumes about 335 kg of paper every year.
- About 20% of all harvested wood is used to make paper.
- New technologies are being developed to produce paper from non-wood fibres. These include fibrous plants, like hemp and bamboo, as well as the waste products that result from the production of food crops, like flax and bananas.

The timber preferred by sawmill operators to make lumber for construction comes from old-growth forests. These trees are large enough to process through the sawmills. Unfortunately, the old-growth stands of trees sought after by sawmill operators are the same ones that have grown enough lichen to support the woodland caribou. When a stand of old-growth trees is removed, there is a negative effect on the population of woodland caribou due to **habitat destruction**.

habitat destruction: the permanent alteration of vital characteristics in an organism's habitat

Habitat destruction is also part of the reason why the woodland caribou is classified as endangered, as shown in the following table.

Figure D1.52: Clearcutting is one method of removing trees from an area.

CATEGORIES FOR SPECIES AT RISK IN ALBERTA

Category	Description	Examples
Extinct	species no longer exists anywhere	• Banff longnose dace This tiny fish lived in only one marsh fed by a hot spring in Banff National Park. Tropical fish were introduced to the marsh. Chemicals leaked into the marsh from a chlorine pool, and this changed the habitat.
Extirpated	species no longer exists in Alberta but lives elsewhere	• black-footed ferret This small member of the weasel family depended heavily on the black-tailed prairie dog for food and habitat. This species can still be found in the United States.
Endangered	species threatened with imminent extinction or extirpation throughout their range in Alberta	• woodland caribou • swift fox • burrowing owl Both the swift fox and the burrowing owl have experienced a loss in habitat as native prairie grasslands have been converted to farmland. Both species often enlarge the abandoned burrows of the black-tailed prairie dog to make their own dens.
Threatened	species likely to become endangered if the factors that caused its vulnerability not reversed	• anatum peregrine falcon In the 1970s, this species was extirpated from Alberta due to the widespread use of DDT. Captive breeding programs have helped the population recover. Current threats are related to a low availability of quality habitat.
Vulnerable	species likely to become threatened or endangered	• wolverine The wolverine needs large areas of undisturbed northern wilderness forests. Forest fragmentation threatens the wolverine's habitat.

There are large numbers of other species at risk throughout the world. People's desire for natural resources are leading to habitat destruction. Since no species can survive without a suitable habitat, it should not surprise you that habitat destruction is the leading cause of species extinction.

Practice

Use the following information to answer questions 50 to 52.

In the middle of the nineteenth century, it was estimated that the population of prairie dogs in North America was about four billion animals. Once prairie grassland was converted to farmland, the black-tailed prairie dog numbers were dramatically reduced by farmers. The prairie dogs were thought to eat too much vegetation now reserved for cattle, and the entrance holes to their burrows were considered a livestock hazard. To reduce their numbers, prairie dogs were poisoned.

50. The swift fox and the black-footed ferret are two species that feed on black-tailed prairie dogs. Use your knowledge of ecological pyramids to explain what effect the mass poisoning of black-tailed prairie dogs would have on each of these animals.
51. Prairie dogs require a habitat of low grasses for good visibility and hard-packed soil to prevent their burrows from collapsing. In much of southern Alberta, the original prairie grassland ecosystem was converted into farmland to grow tall cereal crops. Explain why habitat destruction is listed as the key reason why the burrowing owl is on the list of species at risk.
52. A keystone species is a type of organism whose disappearance will be followed by a decrease in many other community species. Explain why the black-tailed prairie dog is considered to be a keystone species in prairie grassland ecosystems.

Loss of Biodiversity

Once a web of seismic lines and access roads subdivides a section of boreal forest, other human activities can reduce the ability of the forest to recover. Local residents who drive vehicles such as quads can use these seismic lines for recreational purposes—in this way, the vegetation never has a chance to recover and fill in these gaps. As a result of habitat fragmentation and disturbance, species like the woodland caribou and the wolverine experience a decline in numbers and, eventually, are extirpated from that tract of forest. When these two species leave the area, the variety or diversity of life is diminished. Ecologists would say that this area of forest has suffered a loss of **biodiversity**.

Biological diversity is important because areas like Alberta's boreal forest are communities of organisms that not only interact through food webs but also act in concert with geochemical cycles in complex ways that scientists are still struggling to understand. If species are removed that other organisms depend upon, the ecosystem may no longer function. This has serious consequences because the boreal forest cleans water, acts as a sink for carbon, and produces the oxygen organisms breathe. It has been said that if the tropical rain forest is one lung of Earth, the boreal forest is the other.

The boreal forest stretches from northern Alberta to d from northern Europe to ria. Ten percent of Canada's oreal forest is in northern Alberta. Although no one really knows all the long-term consequences of the loss of biodiversity from deforestation, the fact that human activity is inflicting serious damage on the planet's "lungs" cannot be ignored.

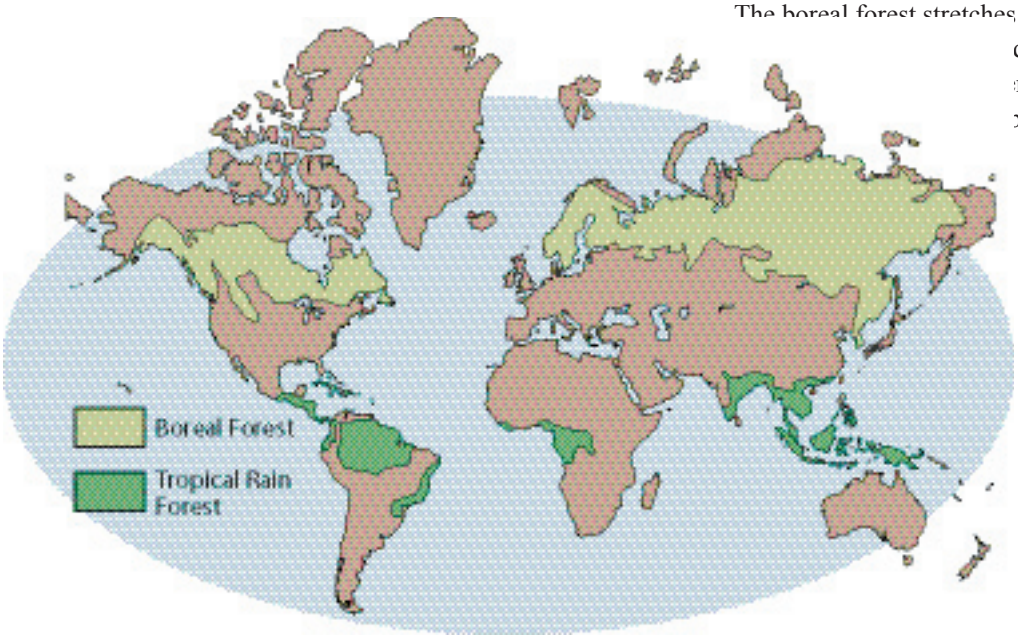


Figure D1.53: The world's boreal forests and tropical rain forests are highlighted on this map.

biodiversity: the variety of life in all its forms, including ecosystem diversity, species diversity, and genetic diversity

What scientists do know about biodiversity is that more than 40% of all prescription drugs are based on compounds discovered in natural species. The Pacific yew was once discarded and was often burned after clearcutting in the forests of British Columbia. A substance in the bark of this tree, called paclitaxcel (under the brand name Taxol), has been identified as a promising treatment for ovarian cancer and breast cancer.

Scientists also know biodiversity ensures that there is a genetic reservoir of plants. From this collection, other varieties can be developed that are more drought and pest-resistant than those currently farmed. In the 1970s, a species of wild corn growing on a hillside in Mexico was used to stop a leaf fungus that had destroyed 15% of the United States corn crop.

Biodiversity and the health of natural ecosystems are the basis of a multimillion dollar tourism industry that supplies people with recreation, spiritual fulfilment, and quality of life. Clearly, it is in everyone's interest to maintain biodiversity.

Figure D1.54: Some of the benefits of biodiversity are shown.

Practice

53. Outline the importance of Earth's boreal forest to the entire biosphere.
54. Explain how biodiversity is linked to the health of boreal forest ecosystems.
55. Why is it in the best interests of people to maintain Earth's biodiversity?

Invasive Species

People sometimes introduce a new species into an ecosystem, either intentionally or unintentionally. Since these new species invade an already established ecosystem, they are called **invasive species**.

These invading species often cause problems for native species. For example, the zebra mussel was introduced into the Great Lakes by the release of bilge water from ships that had travelled to Canada from western Asia. The zebra mussel is actually a native of the Caspian Sea. The ability of the zebra mussel to out-compete native species of mussels for nutrients and a lack of natural predators allowed the zebra mussel population to grow at a very fast rate. The density of zebra mussels in some parts of the Great Lakes is more than 20 000 individuals per square metre. The booming population of these mussels affects the entire food chain because of this species' intensive feeding on the photosynthetic micro-organisms forming the first trophic level for the Great Lakes ecosystem. This means that less food is left for other organisms. Since native species suffer a decline in numbers, the presence of zebra mussels instead of native mussel populations leads to a loss of biodiversity. In the next "Utilizing Technology" you will have an opportunity to develop a profile of an invasive species in Alberta.

Figure D1.55: Zebra mussels are an invasive species to the Great Lakes.

invasive species: a species that does not normally occur in an area, is introduced by human action, and then expands to become a breeding population that threatens the area's biodiversity

Utilizing Technology

Purple Loosestrife—An Invasive Species

Purpose

In this investigation you and your partners will develop a concise bulletin to inform the general public about an invasive species in Alberta—the purple loosestrife. Your bulletin could take the form of a poster, a multimedia presentation, or some other type of presentation to your class.

Science Skills

- ✓ Initiating and Planning
- ✓ Performing and Recording
- ✓ Analyzing and Interpreting
- ✓ Communication and Teamwork

Materials

Assemble the necessary materials for the bulletin format that your group plans to develop.

Procedure

step 1: Read through the entire procedure, and then decide how you will divide the tasks.

step 2: The first task is research. Use the Internet and other resources to determine answers to the following questions:

- What is purple loosestrife and how did it come to Alberta?
- How can purple loosestrife be identified?
- Which ecosystems in Alberta are threatened by purple loosestrife?
- How does purple loosestrife contribute to a loss of biodiversity in Alberta?
- What should you do if you come across purple loosestrife?

step 3: Plan how you can clearly communicate answers for the five questions of step 2 by using your chosen format. Your bulletin should be concise and effective.

step 4: Carry out the plan you devised in step 3 by preparing your bulletin about purple loosestrife.

step 5: Share your bulletin with other students.

step 6: View the bulletins of other students.

Evaluation

1. Ask your classmates for feedback on the bulletin produced by your group. How effectively did your group's bulletin address the five key questions? What aspects of your bulletin could be improved?
2. What did you learn from the bulletins prepared by other groups? If you were to complete this activity again, what would you do differently?

Two Different Systems: Economic and Ecological

You read about habitat fragmentation, habitat destruction, and invasive species. These are serious problems. The prairie grassland ecosystem—complete with bison, prairie dogs, and burrowing owls—has been replaced by modern agriculture. The original prairie grassland ecosystem is largely gone. The boreal forest ecosystem in Alberta is suffering such stress that future generations may never be able to see the same plants, animals, and landscapes that made up the natural boreal forest ecosystem.

Why is all of this happening? Most ecologists trace the source of these problems to a conflict between two very different systems. The economic system provides people with employment and the means to buy goods and services that have become a part of modern life. The ecological system provides people with clean air, water, and food—the life-support system for humans and for every other organism on Spaceship Earth. As the upcoming table comparing ecological and economic systems will indicate, it is the fundamental differences between these two systems that is at the heart of many debates concerning land use in Alberta.

Figure D1.56: The traditional prairie grassland ecosystem—which featured countless bison—has been replaced by modern agriculture. Note the bison skulls from the 1870s. The bones were harvested for money, and this resulted in the destruction of the huge bison herds.

A COMPARISON OF ECOLOGICAL AND ECONOMIC SYSTEMS

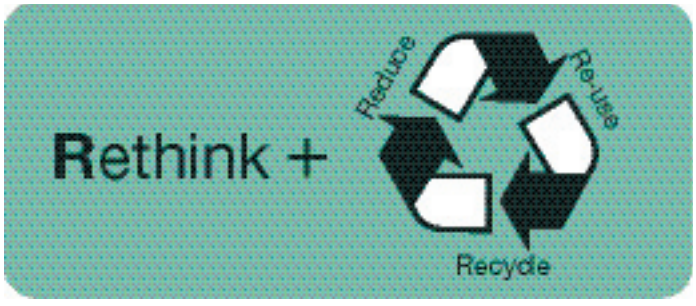
Characteristic	Ecological System	Economic System
time frame	It takes thousands and sometimes millions of years for a new species to emerge—this increases biodiversity. During these long time intervals, species develop intricate patterns of interaction described by food webs.	Most businesses publish performance appraisals every three months. Investors expect a return on investment within a number of years. Government economic policy is often tied to the cycle of elections, which tend to be held every two to five years.
physical environment	The physical environment in which an ecosystem is located is a vitally important characteristic of that ecosystem. The local climate and terrain have a huge effect on the abiotic factors that, together with the organisms, form the ecosystem.	The physical environment is not an important consideration for many businesses. More important characteristics are the availability of cheap labour and low transportation costs. Production is frequently moved from one location to another to take advantage of these factors.
basic units of measurement	Ecological systems are measured in a variety of units that include joules of energy, millimetres of rainfall, biomass per square metre, and the kilograms of CO_2 absorbed per hectare.	The fundamental unit of measure in the economic system is money. The success or failure of a business venture is measured in terms of dollars of profit relative to the dollars invested.

As this table indicates, ecological systems develop over a long time with the physical environment playing a critical role, as measured by such key variables as millimetres of precipitation and joules of solar energy per square metre. By comparison, economic systems develop over a short time with the physical environment playing a minor role in most cases. The biggest difference between the two systems has to do with the units of measurement.

Practice

56. Some ecologists are suggesting that a dollar value be assigned to the ecological services that a forest provides. Services like carbon storage, soil formation, and the maintenance of biodiversity would each be appraised as being worth so many dollars for an area of forest.
    a. Explain how this idea attempts to address one of the fundamental differences between the ecological system and the economic system.
    b. Explain how this system could promote a new style of decision making when it comes to economic development in the boreal forest.
    c. Identify some of the challenges of implementing this approach.

The Fourth R



You have probably heard about Reduce, Re-use, Recycle. Some people would argue that before beginning to reduce, re-use, or recycle, they need to rethink many basic assumptions about the modern lifestyle and the economic system that supports it. The story of a trip to the shopping mall can be used to illustrate how it is possible to rethink lifestyle choices that many people rigidly assume are the only options.

Practice

57. The story of the shopping mall trip, which you read earlier in this lesson, began by sifting through a large pile of advertising flyers.
    a. Identify alternatives to printing advertisements on paper.
    b. What is the connection between paper consumption and the loss of biodiversity?
    c. Identify alternatives to the paper version of this textbook.
58. The story included a 35-minute drive to the mall.
    a. Describe how urban sprawl contributes to habitat destruction.
    b. Describe how urban sprawl increases people's dependence on fossil fuels.
    c. Explain how urban sprawl leads to habitat fragmentation.

A Mass Extinction

Is it really necessary for a society to continually produce, consume, and then throw away so many things? Has consumerism gone too far? When people begin to rethink many of the assumptions of modern living, the questions that emerge and the new ways of living suggested by these questions may sometimes seem extreme and unreasonable. Ecologists would say that these suggestions are tame compared to the extreme effect that human activity has already had on the environment. Since the Industrial Revolution began in the 1700s, it is estimated that between 10% and 20% of Earth's species have become extinct due to human activity. If the current trends continue, about 50% of Earth's species could be gone by 2100. This means that people are currently living through a mass extinction event. The fossil record indicates that such events have occurred only about five or six times in the past 600 million years. Although no one knows for certain, evidence suggests that previous mass extinction events may have been caused by deep impact collisions between Earth and large meteors or comets.

Some people are critical of the suggestion that the modern consumer lifestyle needs to change. These critics might ask, "Can we afford to make these changes?" Ecologists might respond by asking, "Can we afford not to?"

1.6 Summary

Biodiversity refers to the variety of life within an area. The most common measure of biodiversity is the number of different species living within an area. Maintaining biodiversity is important because if a species is lost from an ecosystem, the loss may have consequences for other species due to disruptions to the ecosystem's food web. Habitat destruction and habitat fragmentation have negative effects on the biodiversity of an ecosystem. The introduction of a new species may upset the normal ecological balance in a given area because there are no natural predators or competitors in that area to control the expansion of new species. Threats to biodiversity may be reduced by addressing some of the fundamental differences between ecological and economic systems and by rethinking many assumptions of modern lifestyles.

1.6 Questions

Knowledge

1. Define each of the following terms.

- **a.** habitat destruction
- **b.** habitat fragmentation
- **c.** invasive species

2. Concisely explain why habitat destruction is a threat to biodiversity. Describe a situation in which a specific animal or plant might be at risk.

3. Explain why maintaining biodiversity is so important.

Applying Concepts

4. List several changes you could make to your lifestyle that would help reduce habitat destruction and habitat fragmentation.

5. Consider your answer to question 4 by taking into account the total number of people on Earth. Explain how even small lifestyle changes can have a profound impact.

6. When people look at photographs of an area covered in litter or of a mountain of trash at an overflowing landfill, their personal reactions to these images can vary greatly. On an emotional level, the responses could include anger, sadness, frustration, or disgust. Among the many possible responses, consider the following:

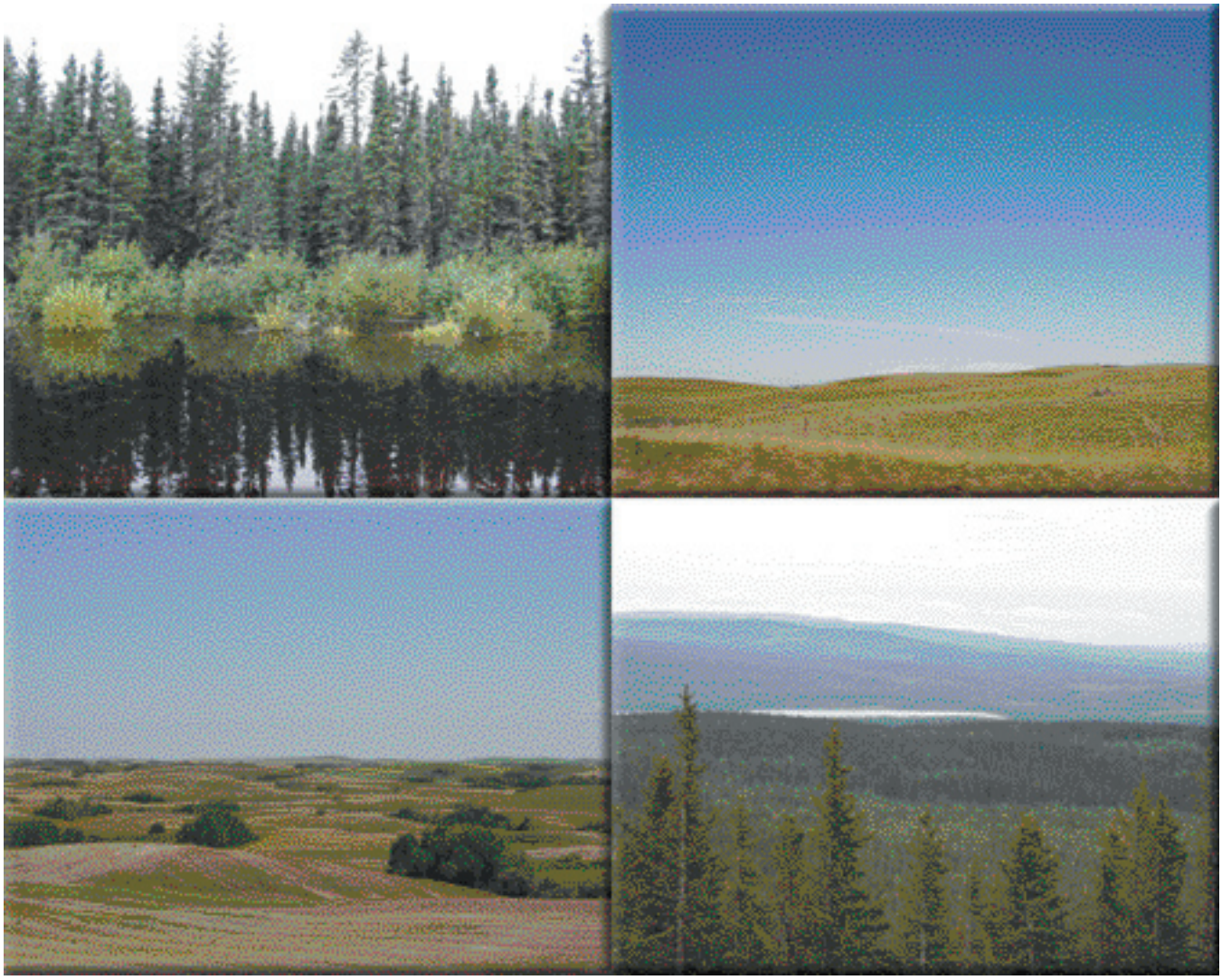
"As a society, if we feel the need to blame someone for these problems all we have to do is look in the mirror."

Use concepts from this chapter to explain this comment's meaning.

Chapter 1 Summary

In this chapter you examined the characteristics of an ecosystem from the point of view of the flow of matter and energy. The investigation of these topics revealed that there are complex interrelationships between species and their environments. Energy pyramids, food webs, and biogeochemical cycles illustrate these complex interactions. The loss of biodiversity indicates how human activities can threaten the long-term health of the world's ecosystems.

The theme of changes in living systems continues in Chapter 2. These changes within the ecosystem will be examined over much longer time frames—from hundreds to thousands to millions of years. The concept of stewardship is seen throughout this unit.



Summarize Your Learning

This chapter demonstrated the interconnections between various forms of life and the physical environment. It will be much easier for you to recall and apply the information you have learned if you organize it into patterns.

Since the patterns have to be meaningful to you, there are some options about how you can create this summary. Each of the following options is described in "Summarize Your Learning Activities" on pages 552 and 553. Choose one of these options to create a summary of the key concepts and important terms in Chapter 1.

Option 1: Draw a concept map or a web diagram.	Option 2: Create a point-form summary.	Option 3: Write a story using key terms and concepts.	Option 4: Create a colourful poster.	Option 5: Build a model.	Option 6: Write a script for a skit (a mock news report).

Chapter 1 Review Questions

Knowledge

1. *Competition*, *transpiration*, *habitat*, *mutualism*, *population*, *trophic level*, and *producer* were terms introduced in this chapter. Determine what term best matches each of the following definitions.

a. a group of organisms all of the same species
b. a division of organisms with a similar nutrition source
c. a symbiotic relationship in which both organisms benefit
d. a loss of water vapour from a plant through its leaves
e. an organism that uses solar energy to make food
f. an area in which an organism lives out its life
g. a struggle between organisms for limited resources

2. For each pair of terms, explain the differences in their meanings.

a. biodiversity, biomass
b. abiotic, biotic
c. food chain, food web
d. producer, consumer
e. habitat destruction, habitat fragmentation

3. Identify three abiotic factors and three biotic factors that describe a forest ecosystem.

4. Why is a food web more realistic than a food chain?

5. Explain the importance of sunlight to an ecosystem.

6. What is a biogeochemical cycle?

7. Identify reasons why the transfer of energy and matter in a food chain is only about 10% efficient.

Applying Concepts

8. The "Interactions Between Species" table summarizes the interactions and relationships between organisms. Complete this table by adding the required information to the missing boxes. Note that the following system is used to describe the effects on a species:

- + means the species benefits from the interaction
- - means the species is harmed by the interaction
- 0 means the species is neither harmed nor helped by the interaction

INTERACTIONS BETWEEN SPECIES

Type of Interaction	Effect on Species #1	Effect on Species #2	Description	Example
	+	+		butterflies and purple coneflowers
	+	0		cowbirds and bison
				tapeworms and bison
predation				
			• interaction where two or more organisms compete for limited resources	

Use the following information to answer questions 9 to 14.

Lemmings

A lemming is a small rodent. It is about 150 mm long with a mass of approximately 80 g. It resembles a hamster. Lemmings live in the high Arctic where permafrost prevents them from digging burrows, so they use natural ridges and depressions in the ground for burrows and travel routes. It is amazing that these tiny animals remain active throughout the Arctic winter, foraging for food in spaces between the ground and the snow cover. As lemmings eat grasses and sedges, they generate wastes that are consumed by bacteria, fungi, and insect larvae, which then return key nutrients to the soil. Lemmings play a significant role in the Arctic ecosystem because they are the main food source for Arctic foxes and snowy owls. Other than human trappers, no animals prey on Arctic foxes.

Other members of this ecological community include musk-oxen and caribou, which both feed on lichens and other small plants. Mosquitoes, black flies, and a number of migratory birds also belong to the group. Musk-oxen and caribou encounter natural predators outside the tundra ecosystem when they migrate south in search of food.

Figure D1.57: Musk-oxen are members of the ecological community in the high Arctic.

9. Sketch a simplified energy pyramid for this ecosystem.

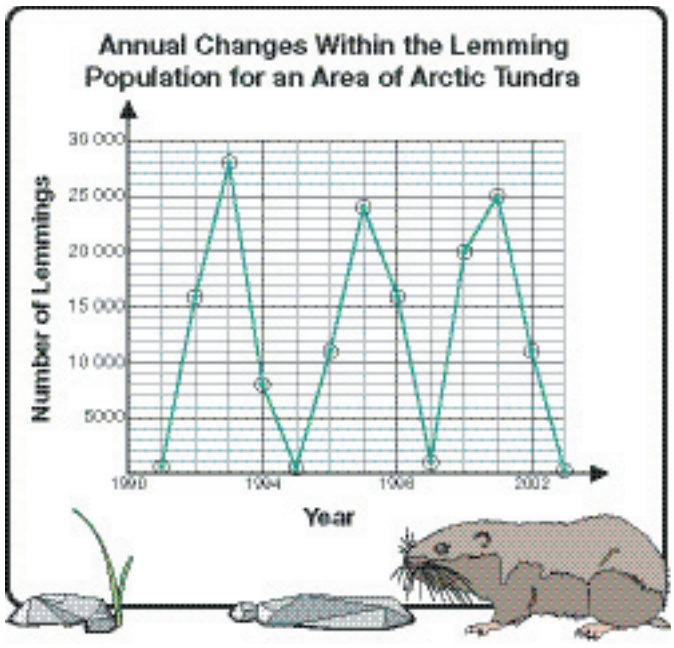
10. Sketch a food chain for this ecosystem that includes the Arctic fox.

11. Suggest a reason why there are no tertiary consumers in this ecosystem.

12. This graph shows how the population of lemmings changes in an area of the high Arctic.

a. A graph of the annual changes within the population of Arctic foxes is related to the graph in this question. Determine the years in which you would expect the population of Arctic foxes to peak. Support your answer.

b. No one really knows the reason for the four-year cycle within the lemming population. One theory has to do with the effect that the lemming population has on the available vegetation. Describe a possible mechanism for this theory.



13. Identify organisms that would be examples of mutualism, competition, and parasitism.

14. The low temperatures of Arctic soils mean that the rate of decomposition is very slow. This, combined with the high water content of ground in the summer, means that much of the tundra is covered in peat bogs or muskeg.

a. Concisely explain whether the tundra is considered to be a sink or a source for carbon.

b. If global warming occurs, explain how your answer to question 14.a. will change.

Use the following information to answer question 15.

Three people gather for lunch. Here's what each person eats.

- The first person eats a piece of chicken. The chicken was fed only plant material.
- The second person eats a vegetable salad. The salad contains no animal products.
- The third person eats tuna from a tin. The tuna was a high-level predator in its ocean environment.

For the purposes of this question, assume that this one meal allows you to categorize the ecological role and trophic level for each person.

15. **a.** Describe each person's ecological role.

b. Determine the trophic level for each person.

c. In reality, you can't accurately classify a person's ecological role based on just one meal. Explain why most people would be classified as omnivores. Refer to the food in a typical lunch to support your answer.

d. Concisely explain why it is not possible for someone at the lunch to have the ecological role of a producer.

16. Use an energy pyramid to explain why it would be very rare for an ecosystem to have a sixth or seventh trophic level.

Use the following information to answer questions 17 to 21.

Biogeochemical cycles typically involve four general steps:

step 1: assembling complex organic compounds from non-living or abiotic parts of environment through process of photosynthesis

↓

step 2: transferring essential elements and compounds to other organisms through trophic or feeding levels

↓

step 3: breaking down complex organic molecules into simpler organic and inorganic forms through process of decomposition

↓

step 4: supplying photosynthetic organisms with raw materials for photosynthesis so process can continue

17. Identify which type of organism assembles complex organic compounds from elements and simple compounds. Support your answer by providing two examples and by describing the process by which this happens.

18. Identify which type of organism feeds on other living organisms as its source of essential elements and compounds. Support your answer by providing three examples.

19. Identify examples of micro-organisms that feed on dead and decaying organic matter as their source of essential elements and compounds. Support your answer by providing two examples.

20. Consider your answer to question 19. Micro-organisms that feed on dead and decaying organic matter return simple compounds to the soil, air, and water. Which group of organisms uses these simple compounds? Support your answer by providing two examples.

21. Describe the carbon cycle in terms of this four-step process.

22. You learned earlier in Chapter 1 that cowbirds lay their eggs in the nests of other birds. These other birds then unknowingly raise cowbird chicks at the expense of their own young, who usually starve or are kicked out of the nest by the larger and more aggressive cowbird chicks. Originally, cowbirds were found on the prairie landscape because they followed bison herds. Cowbirds prefer open spaces to dense forest.

a. Describe how the fragmentation of the boreal forest habitat could allow the population of cowbirds to expand their range farther north.

b. The fragmentation of the boreal forest habitat has reduced the number of songbirds that prefer the habitat of the forest interior to that of the forest's edge. This is because fragmentation creates more edge habitat. Concisely explain why there are also drops in the populations of songbirds that prefer edge habitat in forests where agricultural expansion has fragmented habitats.

23. Late one summer, ecologists discovered that fish were dying in a stream running through some farmland where nitrogen fertilizer was used to improve crop growth. Suggest an explanation for these events.

24. Compare and contrast the relationships of predation and parasitism.

25. Use your knowledge of the energy pyramid to describe the advantages to global ecosystems if more people switched to vegetarian diets.

Use the following information to answer questions 26 to 28.

Locate the video clip called "Career Profile: Rehabilitating Injured Wildlife" on the Science 20 Textbook CD. Play the video. Use the information provided to answer the following questions.

26. Define the word *raptor*. Support your answer with examples.

27. Describe the biomagnification of DDT through the food chain, and outline the resulting negative impact on the population of peregrine falcons.

28. Describe the potential impact on an ecosystem if the population of raptors within that ecosystem begins to decline.

Ecological Footprint Calculator

In order to live, people consume natural resources for food, transportation, and housing. How much biologically productive land and water is required to provide you with the resources you consume and to absorb the wastes that you generate? The answer to this question is called your ecological footprint.

The ecological footprint is measured in global hectares or hectares of biologically productive space with world average productivity. In 2001 it was estimated that there were 2.3 billion global hectares of biologically productive water surface, made up of ocean shelves and fresh water. At the same time, there were 9.0 billion global hectares of biologically productive land, made up of crop land, grazing land, forest land, and built-up land. Note that the total of 11.3 billion global hectares of biologically productive area on Earth does not include deserts, ice caps, and deep oceans.

The average number of global hectares available for each person is determined by dividing the total number of biologically productive global hectares on the planet by the total number of people. Using data from 2001, the world population was 6.15 billion people, so the average is about 1.8 global hectares per person. Even though this is an estimate—based on many approximations—it is a very useful indicator both for charting trends over time and for comparing the demands put on Earth by people living in different countries.

How does your footprint compare to this value? Are you taking more than you should? You can determine answers to these questions by using the Internet to find an ecological footprint calculator. The ecological footprint calculator is simply an online questionnaire that uses your responses to produce a rough estimate of your ecological footprint.

If you use the key words *ecological footprint calculator* and *Canada*, you should be able to use the Internet to find an ecological footprint calculator.

29. Determine your ecological footprint in global hectares.

30. How many times larger is your ecological footprint than the global value of 1.8 global hectares? If everyone lived like you, how many planet Earths would it take to support the world's population?

31. Return to the ecological footprint calculator. Experiment to see what lifestyle changes you can make to lower your ecological footprint.